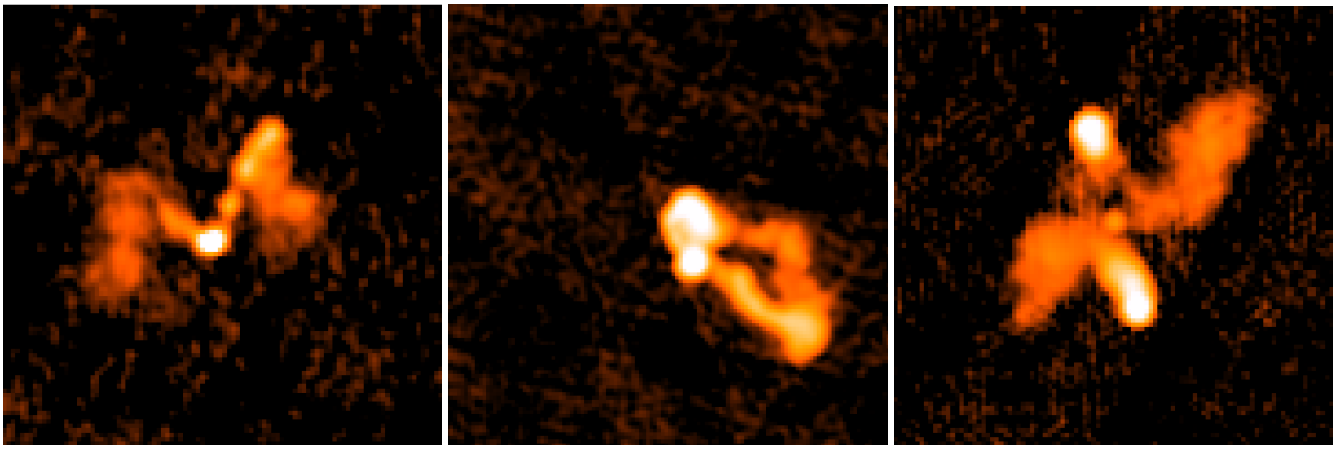
New hints on the nature and evolution of radio galaxies based on ROGUE – the largest human-made catalogue of radio sources with optical counterparts

Galaxies are made up of gas and stars bound by gravity. Most (if not all) galaxies also host a **supermassive black hole** in their core. A fraction of those black holes are active, feeding on the surrounding matter. This matter can be heated to hundreds of thousands of degrees before disappearing into the event horizon, emitting copious amounts of energy in visible light, and also in ultraviolet, infrared and X-rays. Charged particles may also be ejected and guided outwards by magnetic fields, creating giant **jets** of matter and energy that can be observed in, among others, **radio waves**.

Galaxies with active black holes offer a unique perspective in astrophysics. On the one hand, studying galaxies allows us to measure physical properties of their supermassive black holes, whose complete physical description is still **beyond the frontiers of today's physics theories**. On the other hand, the black hole activity gives us clues on the **evolution of galaxies**, which are such complex systems: not only do their stars create most chemical elements in the Universe and their gas is recycled into new stars, but the activity of their central black holes may also be capable of changing the physical conditions of the interstellar gas, and of triggering or halting the formation of new stars.

This project is based on the largest database of galaxies with black holes whose activity is observed in radio waves. The observation of the so-called **radio galaxies** is rather recent, with the first detection of radio galaxies dating back to the 1960s. The first studies contained only a handful of galaxies; in the past few decades radio telescopes surveyed large portions of the sky in search for radio galaxies. Our catalogues ROGUE I, II and III contain over **20 000 radio galaxies** which have been diligently processed one by one. A group of expert radio astronomers classified **by eye** more than 700 000 images in radio and in visible light, a process that avoids false positives and detects features which are just impossible to be picked up by computer-based methods.



Examples of strangely-shaped radio galaxies found in the ROGUE I and II catalogues. After careful by-eye examination, our group found dozens of objects like this. They hold the key to open mysteries in the activity of supermassive black holes in the centre of galaxies.

Combining these careful classifications of radio galaxies with other automated methods (which measure the black hole masses, for instance) and statistical analysis techniques suitable for big data, we can investigate many open questions in the realm of radio galaxies. For instance, we can find out whether the **diversity of radio jet shapes** is due to the jet power or the density of the gas of their host galaxies. We can also investigate why some radio galaxies are bright in the centre and some only at the extremities; why some black holes are active and why some switch off; how small radio emissions evolve to be large jets; and how the black hole activity is related to galaxy-to-galaxy collisions and mergers. Those studies will provide robust clues on the co-evolution of galaxies and their black hole activities which were previously out of reach with smaller data sets.